Northwest Atlantic Fisheries Organization

Serial No. N4269 **NAFO SCR Doc. 00/40**

SCIENTIFIC COUNCIL MEETING – JUNE 2000

An Assessment of the Cod Stock in NAFO Division 3M

by

S. Cerviño and A. Vázquez

Instituto de Investigaciones Marinas, Eduardo Cabello 6, 36208 Vigo, Spain.
e-mail: santi@iim.csic.es, avazquez@iim.csic.es

Abstract

Since 1974, when a TAC was established for the first time, catches ranged from 48 000 tons in 1989 to a minimum of 353 tons estimated for 1999. In recent years most of the catches were taken by non-Contracting Parties. In 1999 the TAC was zero and there was not directed fishery on Div. 3M cod, however catches were estimated in 353 tons, with 350 tons from non-Contracting Parties.

In the 1999 assessment, the status of the stock was qualified as collapse, attributed to three possible factors: a stock decline due to overfishing, an increase in catchability at low abundance levels and a very poor recruitment since.

The EU bottom trawl survey on Flemish Cap has been carried out since 1988. The survey covered all the area where cod occurs. Total biomass was estimated by swept area method showed a peak of 104 000 tons in 1989 and fell since then to the present minimum with 2 596 tons.

Abundance indices at age between 1988 and 1999 are shown in Table 2. Ages ranged from 1 to 12, but the ages older than 7 were rare. Recruitment indices at age 1 in the last four years were at the lowest level since the beginning of the series. The low abundance of those year-classes was confirmed in more recent years, being also scarce in 1999, at ages 1 to 4.

A trend in growth at age along the EU-survey data series was seen. Ages 1 to 4 have been increasing its size all the time. This is probably a population reaction against the decline of the stock. Older ages seldom reacted in the same way.

Introduction

Flemish Cap is an isolated bank separated from the others Newfoundland Grand Banks by Flemish Pass, a channel over 1 100 m depth that limits the migration of the shallowest species. The cod stock on Flemish Cap (NAFO Div. 3M) is considered a discrete population and it mainly occurs in the shallowest area, less than 500 m depth.

In the 1999 assessment, the status of the stock was qualified as collapse, attributed to three possible factors: a stock decline due to overfishing, an increase in catchability at low abundance levels and a very poor recruitment since (Vazquez et al., 1999).

Since 1974, when a TAC was established for the first time, catches ranged from 48 000 tons in 1989 to a minimum of 353 tons estimated for 1999. Annual catches were about 30 000 tons in the late-1980s, when the fishery was under moratoria, and they declined since then as a consequence of the stock collapse.

In recent years most of the catches were taken by non-Contracting Parties. They took one third of the total catch in 1998. In 1999 the TAC was zero and there was not directed fishery on Div. 3M cod, however catches were estimated in 353 tons, with 350 tons from non-Contracting Parties.

Last year analytical assessment showed the stock at its lowest level. This assessment is now updated with the new catch data from the fishery and the EU-survey results.

Assessment

Catches

Total catches since 1959 were revised and updated by Vázquez et al. (1999). Total catch in 1999 was estimated as 353 tons, the lowest in the time series (Table 1; Figure 1).

There has not been directed fishery for cod in Flemish Cap in 1999. Portugal has reported a catch of 2.9 tonnes as by-catches in the redfish fishery (Vargas et al, 2000). Catches of Non-Contracting Parties were estimated as 350 tons based on Canadian Surveillance reports.

Biological information on commercial cod catches is only available from the Portuguese fleet in July, although both catch and sampling were very small: 2.9 tons catch and one sample with 27 fish measured and aged. The mean length and the mean weight in the catches are 59.2 cm and 2083 g. The 1994 and 1993 year-classes, ages 5 and 6 in 1999, dominated the catches, as well as in 1997 and 1998. No data on CPUE were available.

Surveys

Abundance indices and biological sampling are available from the Canadian survey from 1977 to 1985, from Russian survey from 1977 to 1996, with a gap in 1994, and for EU survey from 1988 to 1999 (Figure 2).

Canadian survey results were not used in the tunning of the XSA analysis due to their low effect on the present situation. Data from the Russian survey were also not used due to their poor results in previous catchability analysis (Vázquez and Motos, 1998).

The EU bottom trawl survey on Flemish Cap has been carried out since 1988 (Vazquez, 2000). The survey covered all the area where cod occurs. Total biomass was estimated by swept area method showed a peak of 104 000 tons in 1989 and fell since then to the present minimum with 2 596 tons (Table 2).

Abundance indices at age between 1988 and 1999 in the EU-survey are shown in Table 2. Ages ranged from 1 to 12, but the ages older than 7 were rare and they are joined as group 8+. Recruitment indices at age 1 in the last four years were at the lowest level since the beginning of the series. The low abundance of those year-classes was confirmed in more recent years, being also scarce in 1999, at ages 1 to 4.

Figure 3 shows a trend in growth at age along the EU-survey data series. Ages 1 to 4 have been increasing its size all the time. This is probably a population reaction against the decline of the stock. Older ages seldom reacted in the same way (Table 3).

Catch-at-age in numbers

Total catches in 1999 were estimated as 353 tons; 350 tons taken from non-Contracting Parties (99%) and 3 tons from Portugal (1%). Catch sampling was only available from Portugal and it was judged inadequate to represent all the catch. In order to palliate this problem we use the 1999 EU-survey age composition to estimate catch at age of the total catch. The same catch at age distribution was observed in both commercial catches and the EU survey in most recent years, for example in 1997 and 1998 (Figure 4). Reasons for this coincidence are, first,

only two year-classes dominate stock and catches, and second, the small size cod, where catchability differences between both systems are expected, was scarce. The limited catch sample available for 1999 (Vargas et al., 2000) also points to the same age composition.

Mean weight-at-age in the catch was also calculated using the weight-by-age obtained in the survey.

Maturity ogive.

Last years maturity ogives show a decrease trends in 50% maturation length and age, but the current size is supposed to be close to its biological limit (Saborido-Rey and Junquera, 1999). Table 4 shows the data available. The percentages maturity at age of 1999 were assumed to be equal to those of 1998 because no new information on maturation was available for that year.

Natural mortality was assumed at 0.2

Results

An XSA-Extended Survivor Analysis (Darby and Flatman, 1994) was carried out with these imputs. XSA settings are showed below.

XSA settings

Catch data for 28 years. 1972 to 1999. Ages 1 to 8+.
Tunning with EU-survey for 1988 to 1999 and 1 to 8+ ages.
Tapered **time weighting** was not applied.
Catchability analysis
Catchability dependent on stock size for age 1
Regression type C
Survivor estimates not shrunk to the population mean
Catchability independent of age for ages older than 4
Terminal population estimation
Terminal year survivor estimates not shrunk towards mean F
Oldest age survivor shrunk towards F mean of ages 4-6
0.5 s.e. of the mean to which the estimates are shrunk
0.5 Minimum standard for population estimates from each cohort

Log catchability and its standard error are shown in Table 5, where high standard errors are observed for ages 6 and 7. Results of the catchability analysis for the EU-survey are presented in Figure 5 and catchability residuals seem to be reasonably consistent for ages 1 to 5 but not for ages 6 and 7. Residuals of these two last ages are strongly negative in 1999 and this could indicate an overestimation of their abundance.

Tables 6 and 7 show the XSA results of abundance and F at age since 1988. Since 1995 mean fishing mortality at ages 3-5 decreased until 1999, when it was 0.01, the lowest in the series. Total abundance peaks in 1992 with 154 millions fish and has been decreasing since then until 1999, with 4 millions. Recruitment at age one was scarce since 1993, especially in the last four years. This period with poor recruitments produced a population in 1999 where fish younger than 5-years old are scarce; age 6 is the more abundant class and represents a half of the population abundance.

Biomass, spawning stock biomass, recruitment at age 1 and mean F at ages 3 to 5 were calculated from XSA results and are presented in Table 8. Recruitment at age one present three peaks (Figure 6), 1973-74, 1985-87 and 1991-92, consequently total biomass presents also three peaks in 1976-77, 1988-90 and 1991, the latest being the less important. The relative high abundance of those year-class is also observed in the SSB they produce years later, those peaks of 1977-79, 1989-92, but no in a later data that should be corresponded to the latest recruitment

peak of 1991-92. This could be a consequence of the overfishing at that time; in 1989-90 catch peaks coinciding with high biomass (Figure 7); the biomass decreased in following years but F increased in 1992-95, overfishing the year-classes that produced the last recruitment peak. After 1995 biomass decreased to a level around 10 thousand tons.

In 1999 biomass shows a small increase with respect to 1998, but high negative residuals in catchability analysis for ages 6 and 7 do not offer confidence on its. Age 6 was the more abundant in 1999 and its overestimation also produce an overestimation of the 1999 total biomass. SSB increases also as consequence of both, age of the population and unreal increase in 6 and 7-year classes abundance.

Last years recruitment was at its lowest observed level, suffering a constant fall from 69 millions fish in 1991 to 42 thousands in 1999. Since 1988 to 1990 the recruitment was relatively low, around 20 millions fish; this feature and the high fishing mortality observed since 1991 (Figure 6), with peaks at F=1.6 and F=1.3, as well as the persistence in fishing at low abundance levels, produced the present depleted situation.

The stock-recruitment relationship using both SSB and recruitment at age one from XSA results is presented in Figure 8. Recruitment and SSB since 1994 are the lowest in the series. Two different zones could be pointed in this graphic where the probability of getting good recruitments is different; the average recruitments is 14 millions fish when SSB was below 14 000 tons and it was 48 millions when SSB was above this amount. This value, 14 000 tons, might be considered as a preliminary estimate of B_{lim}.

Discussion

The total biomass indices from the EU survey show somewhat different view in 1999 compared to XSA results. The survey indices continued falling from 8 000 tons in 1996 to 2 500 in 1999, whereas XSA results show a light increase, from 9 000 to 12 000 tons in the same period. Recruitment at age one in VPA shows a similar pattern as the EU survey along the analysed period.

The abundances estimated by XSA show some discrepancy with respect to the survey indices in the oldest ages, six and seven. This discrepancy was also observed in last the year analysis for the same year classes, as well as in retrospective analysis. These year classes represent the most of the population in 1999, so discrepancies in that year-classes abundance produce different trends of the total biomass in both survey and XSA results; whereas survey biomass decreased in the last four years, XSA biomass increased lightly. The reasons for this discrepancy are unclear, but we indicate two possible causes: first, survey vessel could be less efficient to catch big fish than commercial fleetand the 6 year-old class dominates the population; and second, change in fleet catchability could be a consequence of the high aggregations of cod at low abundance; it was observed that cod on Flemish Cap shrunk its distribution towards the shallowest area of the bank, whereas abundance decreases.

But discrepancies between XSA and survey results already pointed, do not invalidate the main conclusion of the analysis: both total biomass and SSB are at the lowest observed level, and recruitment in the last four years were the weakest observed. The XSA shows a more optimistic view than the survey results but the differences are meaningless. The SSB at the low current levels was not able to produce good recruitments in recent years. With the present age structure of the population it is unlikely a recovery of the stock in a short or medium term.

Acknowledgements

This study was supported by the European Commission (DG XIV, Study 96-030), CSIC, IEO, IPIMAR, and the Basque Government. We express our gratitude to Chris Darby from Lowestoft (UK) for his helpful advise.

References

Darby, C. and S. Flatman. 1994. Virtual population analysis: version 3.1. (windows/DOS). User guide. *Min. Agric. Fish. & Food*, Lowestoft.

Saborido-Rey, F and S. Junquera. 1999. Sexual maturity and spawning biomass of the cod stock on Flemish Cap (Division 3M). *NAFO SCR Doc.* 99/29.

Vargas, J. R. Alpoim, E. Santos and A.M. Avila de Melo. 2000. Portuguese research report for 1999. *NAFO SCS Doc*. 00/16.

Vázquez, A. 2000. Results from the bottom trawl survey on Flemish Cap of July 1999. *NAFO SCR Doc.* 00/9.

Vázquez, A. and L. Motos. 1998. An assessment of the cod stock in NAFO Division 3M. *NAFO SCR Doc.* 98/52.

Vázquez, A. L. Motos and J.-C. Mahé. 1999. An assessment of the Cod Stock in NAFO Division 3M. *NAFO SCR Doc.* 99/56.

Table 1. Catch and TAC in tons (‘000)

Year	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Catch	38	48	60	34	42	40	32	27	34	56	23	25	22	22	27	33	30	10	14
TAC												40	40	40	25	40	40	13	12.7
Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Catch	13	10	13	14	15	11	29	48	41	16	25	16	30	10	3	3	1	0	
TAC	12.4	12.4	13	13	13	13	0	0	0	13	13	13	11	11	11	6	2	0	0

Table 2. Abundance index by age from EU Survey (‘0000) and biomass in tons by swept area method .

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8+**	**Total**	**Biomass**
1988	458	7196	4037	1085	128	22	28	11	12965	37127
1989	2418	6062	6964	2819	227	33	12	8	18543	103644
1990	237	1179	467	1588	1453	394	32	24	5374	55360
1991	13780	2560	1538	193	628	168	31	6	18904	36597
1992	7118	3706	475	203	33	127	21	2	11685	24295
1993	438	13274	2852	102	127	17	50	10	16870	55642
1994	315	385	2459	456	12	6	0	13	3646	24062
1995	155	1137	123	361	90	1	2	2	1871	8815
1996	4	297	613	82	225	19	1	1	1242	8196
1997	4	14	315	436	36	90	2	1	898	9063
1998	3	8	9	114	145	7	14	1	301	4532
1999	1	8	10	10	66	41	2	1	139	2596

Table 3. Trends in size by age.

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Med.
1	15	16	16	18	18	16	19	17	16	20	20	22	17.75
2	22	22	26	26	29	29	28	30	30	32	34	34	28.5
3	32	33	33	37	37	41	39	37	39	40	43	45	38
4	41	45	45	45	52	50	51	47	44	47	50	51	47.33
5	59	51	54	55	56	62	59	58	52	51	56	57	55.83
6	71	61	64	65	64	63	73	66	62	60	59	62	64.17
7	84	76	75	72	68	70	73	83	76	59	68	70	72.83
8	89	89	84	70	88	84	84		82			79	83.22
9		92	92	101				87			91		92.6
10		115	97	54			97	103					93.2
11				117	115								116
12										100			100

Table 4. Madurity ogive.

	1	2	3	4	5	6	7	8+
1972	0	0	0	0	0.5	1	1	1
1973	0	0	0	0	0.5	1	1	1
1974	0	0	0	0	0.5	1	1	1
1975	0	0	0	0	0.5	1	1	1
1976	0	0	0	0	0.5	1	1	1
1977	0	0	0	0	0.5	1	1	1
1978	0	0	0	0	0.5	1	1	1
1979	0	0	0	0	0.5	1	1	1
1980	0	0	0	0.01	0.4	0.89	0.99	1
1981	0	0	0	0.02	0.1	0.28	0.84	1
1982	0	0	0	0	0.02	0.33	1	1
1983	0	0	0	0	0	0.07	0.65	1
1984	0	0	0.27	0.49	0.29	0.56	1	1
1985	0	0	0	0.12	0.11	0.21	0.47	1
1986	0	0	0	0.04	0.65	0.94	1	1
1987	0	0	0	0.05	0.1	0.63	0.75	1
1988	0	0	0	0.07	0.33	0.67	1	1
1989	0	0	0	0.07	0.38	1	1	1
1990	0	0	0	0.17	0.72	1	1	1
1991	0	0	0	0	0.19	0.39	0.5	1
1992	0	0	0	0	0.29	0.25	1	1
1993	0	0	0	0	0	0.46	1	1
1994	0	0	0.04	0.67	0.91	1	1	1
1995	0	0	0	0.32	1	1	1	1
1996	0	0	0.04	0.6	0.92	1	1	1
1997	0	0	0.04	0.6	0.92	1	1	1
1998	0	0	0.2	0.86	1	1	1	1
1999	0	0	0.2	0.86	1	1	1	1

Table 5. Log catchability and standard error.

Age	Mean	s.e.
1	-3.04	0.75
2	-1.99	0.54
3	-2.26	0.45
4	-2.56	0.41
5	-2.66	0.86
6	-2.66	1.08
7	-2.66	1.18

Table 6. Fishing mortalility from VPA

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	0.0001	0	0.0003	0	0	0	0	0	0	0	0	0
2	0.0617	0.0042	0.0156	0.0278	0.3611	0.059	0.479	0	0.025	0	0	0
3	0.4095	0.4182	0.24	0.5007	0.9793	0.688	1.22	0.177	0.129	0.369	0.075	0.013
4	0.5188	0.8236	1.045	0.3537	1.3596	1.23	1.166	1.394	0.327	0.198	0.121	0.016
5	0.5378	1.196	1.3004	0.5992	2.2893	1.129	0.388	2.272	0.931	0.245	0.106	0.002
6	0.6794	0.8827	1.1621	0.7108	1.5598	2.354	0.709	3.764	0.415	0.694	0.074	0.001
7	0.593	0.998	1.1839	0.5655	1.7645	1.549	0.852	2.52	0	0.42	0.085	0.011
F 3-5	0.4887	0.8126	0.8618	0.4845	1.5427	1.016	0.925	1.281	0.462	0.271	0.101	0.01

Table 7. Abundance by age (‘000) from VPA.

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1	16915	22091	27643	69104	63013	4324	9724	4442	182	122	89	42	0
2	64683	13848	18087	22626	56577	51591	3540	7961	3637	149	100	73	35
3	84173	49791	11291	14578	18017	32281	39835	1796	6518	2904	122	82	60
4	30472	45758	26832	7272	7234	5540	13282	9631	1231	4691	1645	93	66
5	3717	14849	16441	7726	4180	1521	1326	3389	1956	727	3151	1193	75
6	928	1778	3677	3667	3474	347	403	737	286	631	466	2321	975
7	778	385	602	942	1475	598	27	162	14	155	258	354	1898
8+	396	352	183	192	611	291	345	268	0	0	27	492	685
Total	202063	148853	104755	126107	154582	96493	68483	28386	13824	9379	5858	4650	3793

Table 8. Recruitments at age 1 (‘000), total biomass, spawning stock biomass (SSB), landings (tons), mean F at ages 3-5 and biomass index from EU-survey

	Recruit (1)	Biomass	SSB	Landings	F 3- 5	EU-surv (t)
1972	18862	83839	40474	57503	0.689	
1973	66656	46551	21415	22900	0.569	
1974	134642	37830	14414	24938	1.289	
1975	24748	49619	8240	22375	0.606	
1976	11149	113367	9973	22266	0.334	
1977	3587	87522	22762	27019	0.465	
1978	22809	56866	28587	33131	0.453	
1979	16323	46632	32507	29710	0.725	
1980	8601	32025	14794	10468	0.51	
1981	23513	32258	9477	13873	0.452	
1982	23452	30799	11961	12753	0.487	
1983	14211	43283	13264	10215	0.233	
1984	15865	40544	17071	12702	0.226	
1985	64078	38376	19549	13675	0.525	
1986	128066	37125	13467	14518	0.692	
1987	79904	56875	13059	10632	0.424	
1988	16915	71673	14234	28899	0.489	37127
1989	22091	111086	20381	48373	0.813	103644
1990	27643	67798	24745	40827	0.862	55360
1991	69104	48410	21266	16229	0.485	36597
1992	63013	61080	21412	25089	1.543	24295
1993	4324	47532	6326	15958	1.016	55642
1994	9724	49481	5550	29916	0.925	24062
1995	4442	23938	8636	10372	1.281	8815
1996	182	8666	2000	2601	0.462	8196
1997	122	9199	2109	2933	0.271	9063
1998	89	9259	4548	705	0.101	4532
1999	42	11736	10408	353	0.01	2596

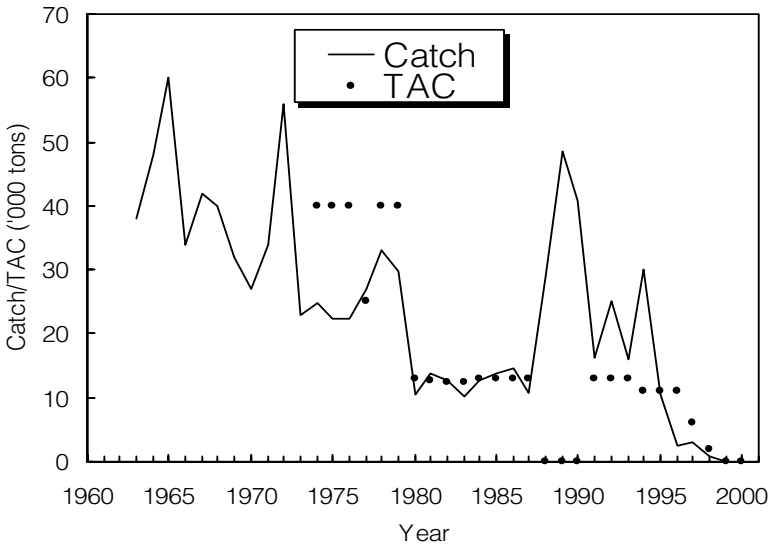

Figure 1. Catch and TAC in tons ('000)

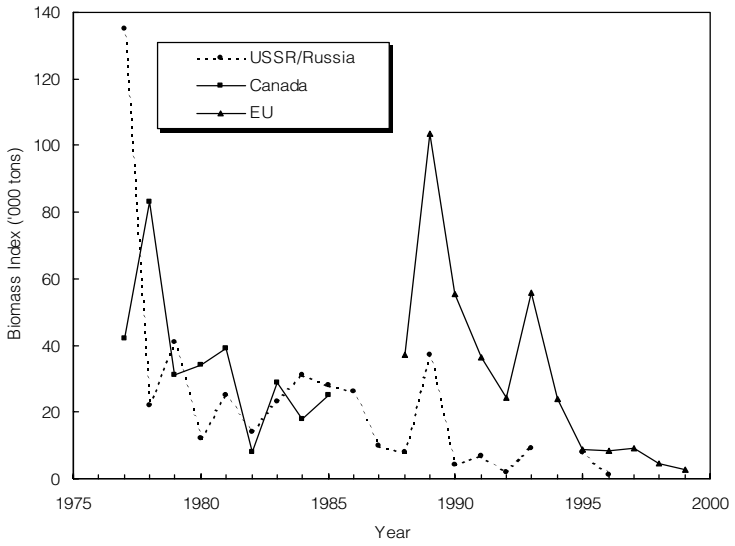

Figure 2. Biomass index from surveys.

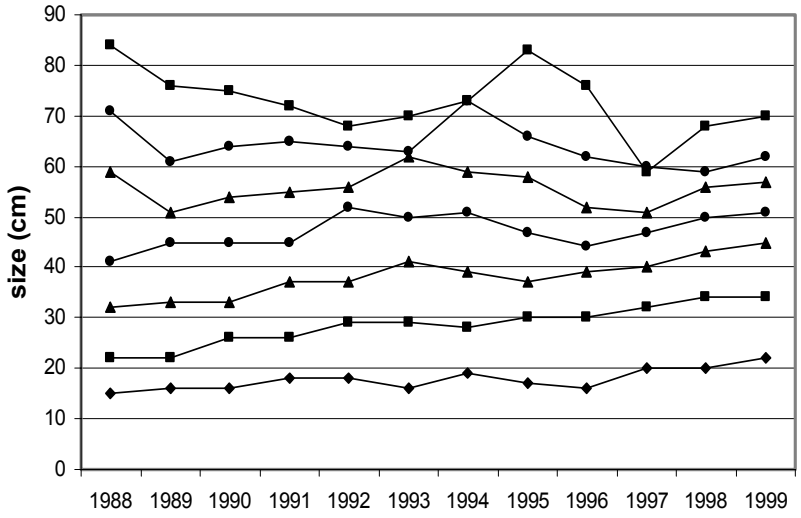

Figure 3. Trends in size by age.

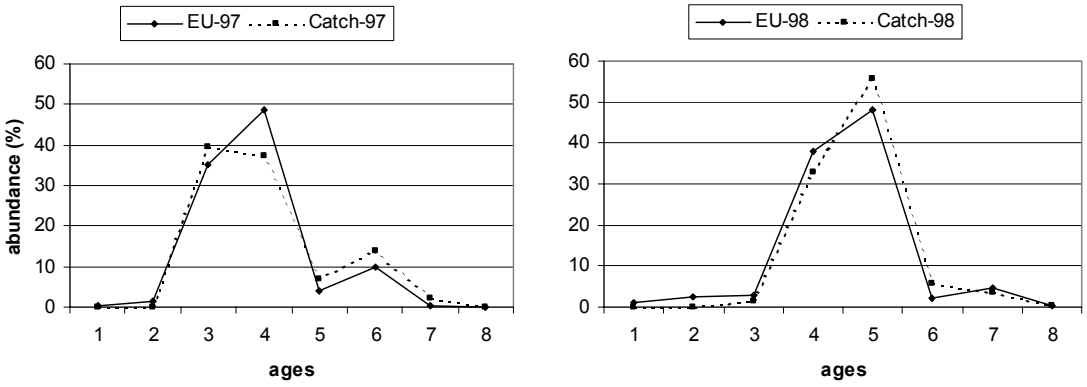

Figure 4. Relationship in abundance by age (%) betwen catches and survey index, in 1998 and 1997.

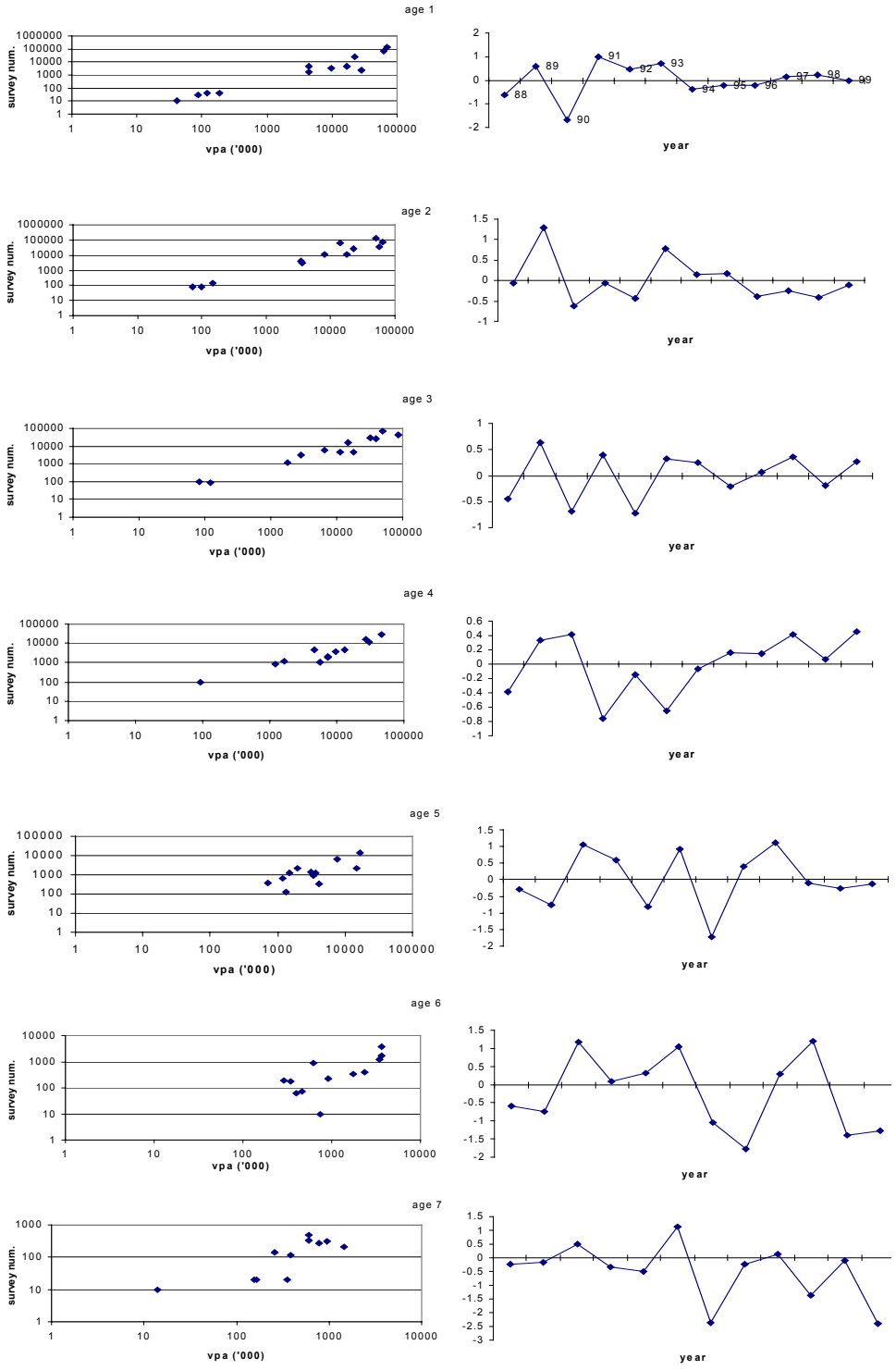

Figure 5. Plot of catchability analysis by age. Left: Abundance index from EU-survey against vpa results. Right: Catchability residuals.

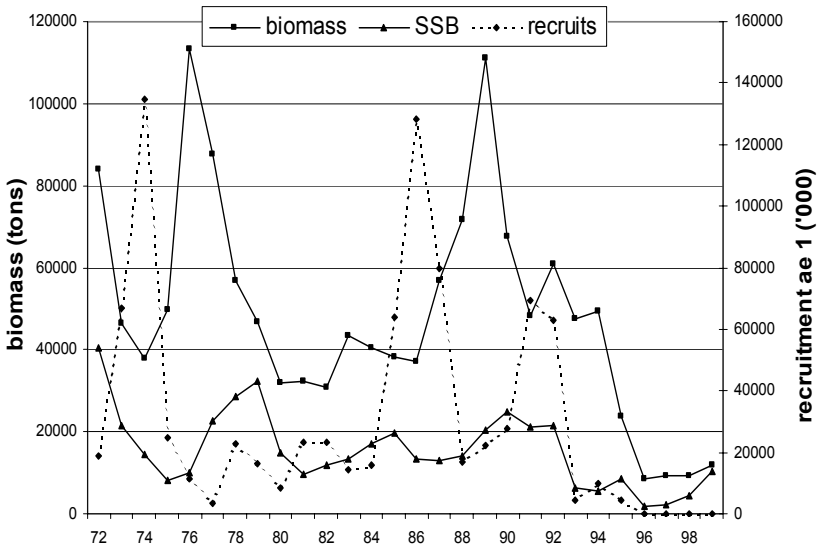

Figure 6 Total biomass, spawning stock biomass and abundance of recruitment at age 1 according to XSA results.

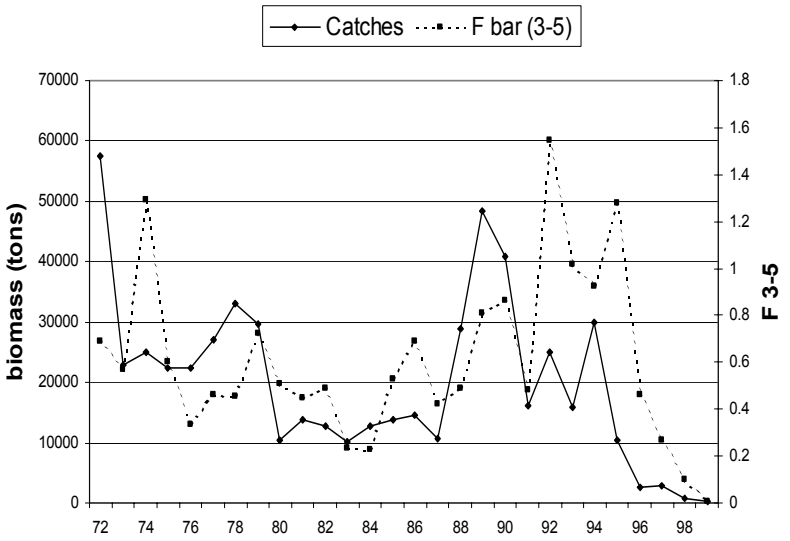

Figure 7. Total annual catch and fishing mortality (F 3-5) according to XSA results

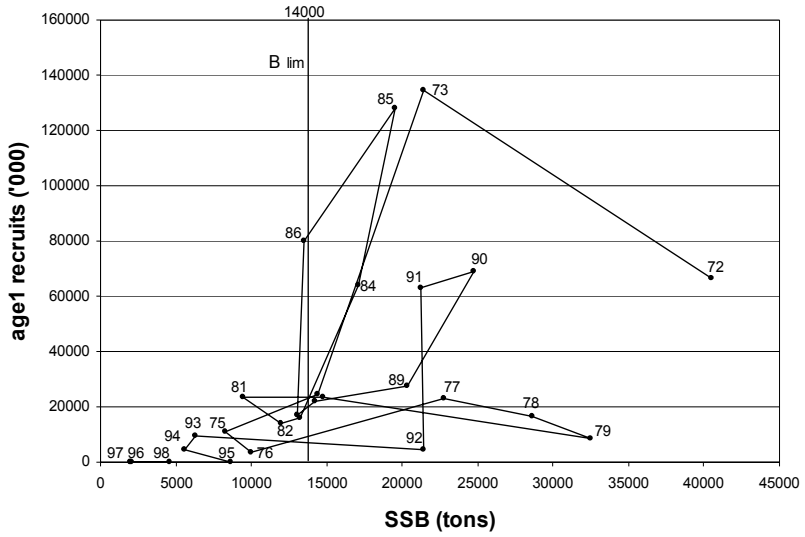

Figure 8. Spawning stock biomass (SSB) and recruitment at age 1 from 1972 to 1998. Tag shows the year of SSB.